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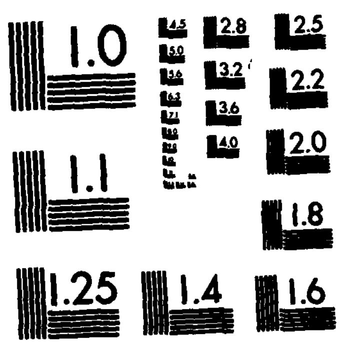

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FOREIGN TECHNOLOGY DIVISION

AIR FORCE SYSTEMS COMMAND

WAVE ABSORPTION MATERIALS USED IN CONCEALMENT TECHNIQUE

by

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FOREIGN TECHNOLOGY DIVISION

Approved for public release; distribution unlimited.

EDITED TRANSLATION

FTD-ID(RS)T-1602-82 13 January 1983

MICROFICHE NR: FTD-83-C-000048

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English pages: 8

Source: Guoji Hangkong, Nr. 9 (235), September 1982, pp. 52-53

Country of origin: China
Translated by: LEO KANNER ASSOCIATES
F33657-81-D-0264
Requester: FTD/SDN

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WAVE ABSORPTION MATERIALS USED IN CONCEALMENT TECHNIQUE

Liu Junneng

I. Foreword

With the development of a detection technique using radar and other devices, there is an important problem facing the design of the next generation of aircraft: how can the penetrating and survival capabilities of military aircraft be enhanced? In the past two decades, the United States and Soviet Union engaged in intense secret research on enhancement of penetration and survival in order to seek air superiority. The successful development of concealment ("invisible") aircraft in the United States is the direct result of this competition.

The concealment technique is a comprehensive technique. In other words, the new aircraft model is designed based on a system engineering concept in which the aircraft has low detectability to an electromagnetic system, infrared system, or other electroacoustic detection systems. This technique includes design and layout of a special exterior of the airplane structure, application of electromagnetic wave absorption materials, the technique of lowering infrared radiation and visual characteristics, and a source interference technique. By coordination and application of various techniques, the overall performance of the aircraft can be optimized so that the aircraft can escape early detection by air defense detecting devices.

II. Functions of Wave Absorption Materials

Appropriate aircraft exterior and layout lead to an effective method of reducing radar reflection characteristics of aircraft; the fundamental principle lies in eliminating or reducing mirror surface scattering within a wide visual angle, in eliminating the geometric composition of the aircraft playing the role of angle (of jump) reflector, in reducing the fringe and terminal tip scattering, in changing the scattering direction, and in covering those intense scattering parts that technology so far is still unable to conceal. The adopted methods include inclined dual drooping tails, low lying delta wings in an integrated wing fuselage entity, superimposed air intake passage, and totally or semiburied cockpit. The result is very significant after these measures are taken; the radar cross sectional area (about 100 square meters) of a long range bomber can be reduced to one tenth of the original figure, the level of a fighter plane at 5 to 15 square meters. Apparently, this has military significance. However, the special exterior design and layout of an aircraft play a limited role because of aerodynamic limitations. An effective measure of further reducing radar cross sectional area is the use of radar wave absorption materials.

In the general situation, the reflection target of radar can be expressed by the radar's reflection cross sectional area. The lowering of the target's probability of being detected by radar means the reduction of the target's reflection cross sectional area. Because the relationship $D=K\sqrt[4]{\sigma}$ (K is the proportionality coefficient) exists between the magnitude of the radar cross sectional area and the distance D from the detectable target to a radar of the same power, therefore, with the reduction of σ, the detectable distance of the target by radar can be reduced, and consequently, there is less probability of being hit by an attack system using the radar's operational principle. For example, by comprehensive application of exterior design and wave absorption materials, a B-1 bomber has as its radar cross sectional area about 1 square meter, which is less than 1 percent of a B-52. Thus, the detecting distance of a B-1 by radar can be shortened by more than two thirds. It is apparent that by using the concealment technique with proper coordination of conventional interference and other means of concealment, it is possible for an aircraft in the atmosphere to disappear (from radar).

III. Two Main Types of Wave Absorption Materials

In the early 1940s, wave absorption materials began to be used in the camouflage of aircraft against radar detection. In recent years, because of rapid development of modern air defense systems, the military significance of wave absorption materials became more apparent; these materials are considered military materials under major research, and are stressed by the world's technologically developed countries. The wave absorption materials used for concealment of flight vehicles should have the characteristics of a wide absorption frequency band and light weight; the materials should meet aerodynamic requirements during high speed flight. At present, there are two main types of wave absorption materials used abroad against radar detection.

1. Antiradar wave absorption coating materials

Considerable developments have been done abroad on coating materials used against radar detection. There are many kinds of wave absorption coating materials, some of which are applied on guided missiles, as well as on F-4, A-7 and F-14 aircraft.

By analyzing the propagation principle of electromagnetic waves in different media, if it is desired to obtain absorption materials of a wide wave band without reflection, the materials should meet the condition $\mu=\varepsilon$. However, up to now technically these materials are still unavailable. Generally speaking, only ferrite can possibly satisfy the condition $\mu=\varepsilon$; at present, few ferrites have been successfully developed, satisfying $\mu_r \sim \varepsilon_r$; and with relatively good band width.

Conducting special research on the radar cross sectional area, the Kangdaotong [transliteration] Company of the United States manufactured a series of ferrite absorption materials: coating layers made of these materials can ensure the absorption of electromagnetic waves within the meter wave and centimeter wave range. The reflected energy can be attenuated by 17 to 20 decibels. The ceramic ferrite structure made by the U.S. company attains the best absorption characteristics. The Boeing Corporation developed a ceramic ferrite material capable of producing angular rotation of the electric field vector; the material has been used in the radar antenna cover of high speed flight vehicles.

In recent years, considerable development was conducted on electric wave absorption materials in Japan by the Tokyo Electrochemical Industrial Corporation, Guanxi [transliteration] Coating Material Company, and Northeast Metal Industrial Corporation. At the Tokyo Electrochemical Industrial Corporation, ferrite powder is blended with Fe_3O_4 powder at a certain weight ratio; the mixture is then scattered in organic polymer materials, such as chloroprene rubber and chlorosulfonate polyethylene rubber. The ferrites are of a nickel zinc system, nickel magnesium zinc system, manganese zinc system, cobalt nickel zinc system, and magnesium copper zinc system. These materials are under development; the thickness is betweel 1.7 and 2.5 millimeters. The reflection attenuation is over 30 decibels when the materials are used at 5 to 10 kilomegahertz. Especially, the Tokyo company is developing an anti-reflection coating material, a spinel type ferrite. When its thickness is 2.5 millimeters, the attenuation to 9 kilomegahertz electromagnetic waves is as high as 24 decibels with quite good characteristics in band width. It was said that this coating material is a key material in concealment technique. At present, the United States is negotiating with Japan for purchase of this wave absorption coating material.

Recently, a coating material was developed abroad to be used for anti-radar camouflage of aircraft; this material is a mixture with 90 percent by weight magnetizable particles (with grain size ranging from 0.5 to 20 microns) scattered in thermosetting adhesive. The particle material can be (magnetizable) iron, or glass microballs coated with magnetizable material. This coating layer is especially suitable to restrict reflection of those parts such as the trailing edge of the wing, and can attenuate energy of 2 to 10 kilomegahertz by 12 to 10 decibels with only a layer thickness of 1 millimeter. This coating material is different from the above mentioned ferrites, as the material can still be magnetized for frequencies higher than 2 kilomegahertz. The coating material is still effective for a temperature as high as 500 degrees Celsius; the material is low in cost and convenient in coating.

There are the following characteristics in using a plasma absorption layer (produced by radioactive isotopes) for antiradar camouflage of aircraft: wide absorption frequency band, high reflection attenuation, long use cycle, simple application, and capability of meeting aerodynamic requirements for high-altitude high-speed flight. In addition, the plasma absorption layer can absorb infrared radiation and acoustic waves, and expel electrostatic charges. The major problem is that the plasma is harmful to the human body due to radioactivity. Therefore, in addition to the selection of adequate radioactive sources, the radiation dosage should be strictly controlled. As revealed in experiments, for a polonium-210 coating layer with a thickness of 0.025 millimeter, the reduction of the radar cross sectional area for 1 kilomegahertz normal incidence electromagnetic waves is 10 to 20 percent. If the coating material is applied to those parts capable of producing multiple reflections, the absorption effect can be doubled.

The coating material for antiradar camouflage is mainly used on those parts of the aircraft surface where metals have to be used, and some other bright spots. There are considerable difficulties in applying absorption coating material on large areas.

2. Structure type wave absorption materials

An ideal absorption material for radar waves should be a material similar to paint, the spraying of which can provide effective protection for various polarizations of electron waves within the range of the incident angle and in a wide frequency range. It is sad to say that such materials are not available now or in the foreseeable future. The available coating materials (even with the best characteristics) present some problems when coated on aircraft or other surfaces, such as loose adhesion and drop off, and increase of aircraft weight in affecting its flight performance. In solving these problems, a kind of structural type wave absorption material came on the market; this is a combination of wave absorption material and nonmetal base composite material, and it has outstanding absorption characteristics for electromagnetic waves, is light in weight and high in strength. When such combination material is used to build an aircraft fuselage, wings and other exposed surfaces, the radar cross sectional area of the aircraft will be greatly reduced. In addition, the combination material reduces the cost and weight of composite and wave absorption materials. At present, this structural type wave absorption material has been successfully applied on the horizontal stabilizing plane of SRAM guided missiles, the engine rectifier cover of F-111 aircraft, and some parts of B-1 aircraft.

The nonmetal base composite material has certain transparency and absorbability for electromagnetic waves. There were early studies abroad using this kind of low reflection materials to build such flight vehicles as cross sectional targets of radar. In recent years, there were rapid developments in such wave absorption materials, so that nonmetal structural materials are used as a carrying body. These wave absorption materials can be prepared using the following methods: One is the absorbent scattering method, scattering the electromagnetic wave absorbent in adhesives, such as epoxy, applying the principle of gradual change of impedance in electromagnetic wave transmission. Another method is to use adhesion or other mechanical means to join the wave absorption material and composite material boards (these two are prepared in advance) into a laminar body. The third method is to prepare a sandwiched structure using boards of composite material (with good wave transparency and high strength) as facing boards of a sandwiched structure. The core can use a honeycomb structure, ripple structure or pyramid structure. Low strength foam absorption material can be used to fill the core layer, or the wave absorption coating material can be sprayed on core surfaces. In this structure, the electromagnetic waves can have multiple reflection and greatly raise the absorption effect.

The Emerson & Cuming Company of the United States manufactured the MC-75 and SF-RB series of honeycomb structure wave absorption materials. The SF-RB series provides the lowest reflection to electromagnetic waves within the range of incident angles between 60° and 85°. When used in (M=2) aircraft, this material was successful in testing. The application frequency of the material is 5 to 16 kilomegahertz; thickness is 3.175 to 5 millimeters; and weight, 7.81 to 9.76 kilograms per square meter. In another example, a kind of laminar absorbent structure is used in the wave absorption material of the B-1 bomber with composite materials (such as reinforced plastics) as the exterior cover, and plate-shaped wave absorption material (such as ANW-73) is placed beneath the cover. A complex honeycomb structure wave absorption material developed by the Rockwell International Corporation is composed of seven layers; the first layer is the surface, made of glass cloth in impregnated epoxy resin. The second through fifth layers are made of glass cloth, absorption layer, and honeycomb absorption layer. The sixth layer is the honeycomb, and the seventh layer is a thin aluminum plate. The joining of different layers is done using solidified epoxy resin. This multilayer material not only has sufficient rigidity, strength and resistance to high temperatures but is also light. Therefore, this seven-layer material is quite suitable to those aircraft surfaces such as its covering skin.

At present, epoxy base composite material developed from reinforced plastics is ahead of others. Composite materials, primarily of carbon-epoxy, have been applied and the use and application range are increasing continuously. This provides very advantageous conditions for preparation of structure type wave absorption materials. It is predicted that large quantities of nonmetal base (wave transparent) composite materials, wave absorption composite materials, or other wave absorption materials will be applied to many parts of the fuselage of future fighter planes.

IV. Conclusion

Reduction of the radar reflection area of an aircraft is the heart of the concealment technique. Appropriate airplane structure types and application of wave absorption materials are the most effective method of reducing the radar reflection surface. Therefore, in the present rapid development of air defense systems, the urgency and importance in developing wave absorption materials are apparent as they are closely related to concealment technology.

The apperance of "invisible" aircraft provides an effective route for aircraft penetration. Undoubtedly, this is a serious challenge to the modern air defense system. The concealment technique opens more complex and new study topics on radar and other detection techniques. This will be an unavoidable electronic warfare, which will lead to modernization of air force equipment toward more advanced development.

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